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Abstract

This paper estimates heterogeneous hedonic prices for different levels of housing space, by exploiting a unique space-adding project in Singapore that added a uniform amount of $6m^2$ of space to each existing housing unit regardless of the original size of the unit. This space adding was part of a large scale urban renewal and housing upgrading policy in Singapore, and was carried out only if sufficient residents within a high-rise building vote in favour of space adding. Using a difference-in-differences strategy after restricting our sample to narrow margins around the voting cut-off, we find that the additional space increased the resale price of a housing unit by 7% on average, and the extent of price appreciation varied significantly across the original size of the units.

This unique social experiment provides the opportunity to compare the differencing-produced implicit price of housing space to that obtained directly from a standard hedonic regression. We find that the differencing methods based on repeated transactions produce slightly lower average implicit price of housing space as those from the hedonic approach, but with a larger variation across the original size of the unit.

JEL Classification: D04, R21, R28
Keywords: housing space, implicit price, hedonic regression, urban redevelopment

1. Introduction

Households choose where to live and which unit to buy by considering a bundle of housing characteristics, and housing space is one of the most important contributors to the total willingness to pay for the unit. From the demand perspective, adequate housing space is a critical screening factor used in narrowing a property search. Space constraint is also a key determinant when consumers decide to upgrade their residence. From the supply perspective, the size of a housing unit is a key parameter that developers adjust to maximize profits.[1] Housing space also plays a pivotal role in designing urban development policies.[2] Given its importance to policy makers as well as to consumers and producers' bid and offer functions that underlie the hedonic price equation, it is essential to have a good understanding of the hedonic price of housing space. However, estimates obtained from a standard hedonic regression could suffer from potential functional form misspecifications and endogeneity arising from omitted variables.[3]

This paper addresses these problems by conducting a model-free estimation of the hedonic price of housing space, using a unique quasi-experiment in Singapore that adds a uniform amount of space to existing housing units regardless of their original size. The Singapore space-adding quasi-experiment is part of an extensive housing upgrading program driven by the need to rejuvenate neighbourhoods concentrated with relatively older and smaller

[1] This is especially so when stringent zoning regulations have been imposed to restrict the floor area ratio. In the standard non-stationary, durable housing models, housing is also often assumed to be externally immutable but internally malleable (see, for example, Anas, 1978; Arnott, 1980; Fujita, 1976).

[2] For example, Shanghai Municipality in China considered that rapidly increasing floor consumption to be the city's first priority when recovering from the Cultural Revolution. With this aim, floor area per person has increased from 3.6 square meters in 1984 to 34 square meters in 2010 (Bertaud, 2011). In addition, according to Deaton (2010), how to deal with the hedonic price for space matters in accounting for housing expenditures in national accounts. This in turn determines the poverty line, artificially moving millions of people in and out of poverty

[3] Since Rosen (1974)'s seminal work on the theory of hedonic prices, empirical applications of his proposed two-step method to recover demand and supply parameters from the hedonic price equation have grown extensively, especially in the housing market. Despite the model's general theoretical soundness, estimations of the hedonic regression have been challenged by potential functional form misspecifications and endogeneity arising from omitted variables (see e.g. Cropper, Deck, & McConnell, 1988; Halvorsen & Pollakowski, 1981; Harrison & Rubinfeld, 1978; Kuminoff, Parmeter, & Pope, 2010 for discussions on hedonic functional form misspecifications and omitted variable bias; Linneman, 1978).

estates. One aspect of this upgrading program involves adding an additional $6m^2$ of space to existing apartments (henceforth referred to as flats) in high-rise buildings (henceforth referred to as blocks), regardless of the original size of the flat. Before the implementation of the space-adding project, residents at each block were polled regarding their preferences for it. The project proceeded for a block if at least seventy-five percent of the block's residents voted in favour of it. This feature of the program lends itself to a natural experiment that allows us to identify the impact of adding space to existing housing units by exploiting the discontinuity at the voting threshold.

We quantify the impact of adding space to existing units using individual flat transactions matched with block-level polling results for the space-adding project. Using a difference-in-differences strategy, we identify the effect of space-adding by comparing the price before and after the upgrading for blocks with space added (the treatment group) versus blocks without (the control group). The main identification challenge is that blocks which voted in favour of the space adding may be unobservably different from blocks that voted against the space adding in ways that are associated with potential future price appreciation. We resolve this issue by comparing blocks with voting results just above the threshold and those just below the threshold. The uniform increase in space, regardless of the original size of the flats, allows us to examine the heterogenous impact of space-adding to flats of differing floor area in a model-free setting, and thereby trace out the shape of the hedonic price function of housing space.[4]

We first document the impact of space-adding on the total value of the units. The space-adding project resulted in an average 7% rise in the value of the flat and the extent of price appreciation varied significantly across the original size of the units. While large units

[4] We argue that the treatment differences between the treated and the untreated are driven mainly by the added space. As will be detailed later, our sample includes only blocks that have proceeded with the standard package of the upgrading program, which involves a general renovation of the block. The space-adding item is an additional package that is offered on top of the standard package.

maintained roughly the same price levels as before, small units experienced substantial price appreciation. For example, units with original housing space less than 55 square meters experienced a 16% rise (or a nominal price increase of S$27,500[5]), while units with original size between 55 and 65 square meters experienced only a 9% increase (or a nominal price increase of S$15,500[6]). The evidence is consistent with a concave-shaped hedonic function tracing the extent to which house price varied with housing space. The declining increase in hedonic price in response to the same uniform change in space, as the original size of the flat increases, is also consistent with theoretical assumptions of diminishing returns in both production and consumption.

Next, we explore whether total house price appreciation is attributable to the increase in space alone, or if it is due to the combined effect of a change in housing space and the average price per unit of housing space. If the marginal price of housing space falls as space increases, we could observe an initial increase in the average price per unit of housing space initially, followed by a plateau, then a decrease when marginal price falls below the average price curve. To study this, we estimate the causal impact of adding 6 square meters of space on the underlying valuation of housing space on a per-square-meter basis. We find that adding 6 square meters of space to units originally smaller than 55 square meters increased per-square-meter price by 10.5%. Together with the added space, this led to an overall price appreciation of 16% documented earlier. For units with housing space between 55 square meters and 75 square meters, per-square-meter price did not change significantly and the total house price appreciation is mainly attributed to the enlarged housing space. For units larger than 75 square meters, per unit price fell by 8-9% following the space adding, but the total value of the units remained roughly the same due to the increase in housing space.

[5] S$27,500 is based on 16% of the mean nominal price of treated flats in our benchmark period.
[6] S$15,500 is based on 9% of the mean nominal price of treated flats in our benchmark period.

These findings contribute to our understanding of the role of housing space in determining the value of a housing unit. Despite its importance, we have only encountered the following three papers that look specifically at the value of housing space. Follain, Lim, and Renaud (1982) use three different methods (direct estimation of demand for space; bid-rent approach; hedonic equation) to estimate the willingness to pay for additional housing space. This is then compared with the cost of additional space to inform public housing policies in Korea. To inform public housing policies in Hong Kong, Hui (1999) also estimates the willingness to pay for additional space using the contingent valuation method via a survey. Gao and Asami (2011), concerned about the distortion in China's urban housing market, use the hedonic approach to figure out people's preferred housing size in urban China. This paper adds to this thin literature by tracing out the shape of the hedonic price function of housing space flexibly, while addressing the problems of functional form misspecifications and omitted variable bias. We also show that the increase in housing value can be driven by a combination of a rise in the average price per unit of housing space and the increase in space itself.

The paper is also related to the literature on hedonic studies, especially those focusing on estimating the impact of temporal variables (Clapp and Giaccotto, 1998; Sirmans et al. 2006). Coulson and McMillen (2008), for example, has focused on isolating the impact of time-varying age on property values by adopting the repeated sales model to difference out characteristics that is time-invariant. Similarly in our unique setting of the space-adding project, the size of the housing unit varies before and after the project implementation, which provides a valuable opportunity to identify the impact of housing size in a repeated sales setting. Similar to the literature, we also contrast our findings to those obtained from the standard hedonic regressions in the Results section.

Comparing the implicit price of housing space estimated from a differencing approach to that obtained directly from a hedonic regression helps access the effectiveness of these two different approaches in calculating the housing price index. Hedonic method is widely used to produce housing price index, but is often criticized for omitted variable bias and arbitrarily imposed functional form. To address these issues, repeated sales method was proposed in Bailey, et al (1963) and Case and Shiller (1989) and further assessed in Hwang and Quigley (2004) and Harding et al., (2007). The idea is to difference out a flexible function of unobserved housing attributes and implicit prices based on a set of repeatedly transacted units. There is, however, no evidence to show that the implicit prices of hedonic attributes differenced out in a repeated sales setting match those estimated from hedonic regressions. This paper utilizes this unique social experiment to identify the implicit price of housing space from a differencing approach and compares that to those obtained from standard hedonic regressions. The evidence suggests that the implicit prices of housing space produced by these two approaches largely match each other, though the differencing approach based on repeated transactions produces larger variation in the magnitude of the implicit price across the original space.

This paper also contributes to the literature that combines quasi-experiments with the hedonic model to address the concern of omitted variables (e.g. Black, 1999; Chay & Greenstone, 2005; Figlio & Lucas, 2004; Gayer, Hamilton, & Viscusi, 2000; Linden & Rockoff, 2008; Jaren C Pope, 2008; Jaren C. Pope, 2008). The space-adding project that proceeded only if sufficient residents voted for it allows us to exploit the discontinuity at the voting threshold to account for omitted variables. The unique policy feature that increased space uniformly regardless of the original size of the housing unit also allows us to relax functional form restrictions on the hedonic price function and to trace out the hedonic price function of space flexibly (see Anglin & Gencay, 1996; Parmeter, Henderson, & Kumbhakar, 2007 for examples of attempts to relax functional form restrictions) We compare our DiD estimates to estimates from the traditional hedonic approach, and find that the traditional hedonic approach slightly overestimates the average price appreciation following the upgrading. In addition, the shape of the curve obtained if we plot average price per square meter against housing space seems to differ across the traditional hedonic and quasi-experiment methods. This could be driven by omitted variable bias or misspecification of the functional form.

Finally, the evidence documented in this paper is also related to the literature on housing upgrading and remodelling. Classical models of urban growth incorporating redevelopment of durable housing suggest that developers respond to the time path of land values and redevelop a parcel if the price of land for new development exceeds the price of land in its current use by the cost of demolition.[7] The demolition cost, even though often assumed away in a simplified theoretical setting, could potentially be substantial due to prolonged household and neighbourhood disruptions.[8] Alternatively, urban renewal might be achieved by upgrading existing properties, which could be a less costly and disruptive approach. This paper provides evidence on the potential benefits of upgrading by examining the extent to which adding space to existing units increases the underlying valuation of existing housing space. The significant price appreciation following the remodelling of small units helps to justify the upgrading program.

The rest of this paper proceeds as follows. Section 2 summarises the relevant institutional background of this upgrading program. Section 3 describes our data and construction of key variables. Sections 4 and 5 explain our identification strategy and empirical specifications. The main results can be found in Section 6. Section 7 concludes.

2. Institutional Background

[7] See Brueckner (1980), Wheaton (1982), and Braid (2001) for models incorporating residential redevelopment into the theory of urban growth with durable housing. See Rosenthal and Helsley (1994) for empirical evidence that supports the validity of the redevelopment condition.

[8] These disruptions include displacement of incumbent residents (who are usually of lower socio-economic status) and the concomitant loss of social networks (Atkinson, 2000; Collins & Shester, 2013; Keating, 2000; Zuk et al., 2015). Even when displacement doesn't occur, gentrification may lead to welfare losses for incumbent residents e.g. in terms of rent increases (Bartik, 1986) and changes in industrial and retail mix which lead to a loss of higher-paying employment for the less-educated (Lester & Hartley, 2014)

The space-adding quasi-experiment is part of an extensive public housing upgrading program in Singapore, driven by the need to rejuvenate neighbourhoods concentrated with relatively older and smaller estates. In this section, we will describe briefly Singapore's unique public housing landscape and elaborate on the upgrading program which the space-adding project is a part of.

2.1. Public Housing in Singapore

Public housing in Singapore[9] (locally known as Housing and Development Board (HDB) flats because they are built by HDB) is provided in the form of 99-year lease-based high-rise flats, and is recognized to be of good quality. The scale of public housing in Singapore is unique. More than 80% of Singapore's resident population live in HDB flats; and about 90% of these households own their flat (HDB, 2016). HDB flats can be purchased directly from the government, with significant government subsidies[10], or from the resale market, where flat owners sell directly to buyers after completing the minimum occupancy period.[11] In this paper, we focus on the resale price of HDB flats as they are market-driven.

HDB flats in Singapore are organised into 26 towns or estates. Each HDB town or estate is divided into neighbourhoods, which are further divided into precincts of 5 – 10 high-rise blocks of HDB flats. Blocks within a precinct are located in close geographical proximity to one another. In addition, they are usually homogenous in terms of quality and design. This is because new flats are typically designed by HDB architects at the precinct level, and pre-fabrication construction techniques (which require a large degree of standardisation) are used.

[9] Residential properties in Singapore are grouped into three categories: private non-landed properties (including private apartments and condominiums), private landed properties, and public housing.
[10] Direct purchases from the government are subject to eligibility criteria, and locations of flats are usually more restrictive.
[11] Owners of HDB flats are not allowed to sell their flats until they have stayed in their flats for a minimum period. This minimum occupancy period is currently 5 years. It was raised from 3 years in 2010.

Within each block, it is also possible to have a mix of different flat-types, e.g. 3-room flats, 4-room flats.

2.2. Upgrading Programs

The quality of HDB flats has varied over the years. Flats built in the early 1960s had minimal features, as the government's priority then was to build sufficient flats to house Singapore's population. Once basic housing needs had been met, HDB started improving the flat quality by building larger and better-designed flats in the 1970s. The improvement in the quality of new flats has continued since then. The continued improvement in flat quality opened a gap in the quality of new and old flats, which led to dissatisfaction with the older flats as well as an exodus from the older to newer estates.

To improve the quality of aged HDB estates, the government has undertaken a series of large-scale upgrading programs.[12] The first of these systematic upgrading schemes was a large-scale upgrading program named the Main Upgrading Programme (MUP), which the space-adding item is a part of.[13] The MUP proceeded in batches (i.e. the MUP was offered to different precincts at different times) and ran from 1990 to 2012, benefiting about 130 precincts spread across Singapore (Chin, 2012). The main criteria for choosing precincts for the MUP for each batch were: (i) age of blocks; (ii) a relatively even spread across HDB towns; and (iii) precincts had blocks with a majority of 3-room flats – relatively smaller flats (Low, 1996). **Figure 1** and **Figure 2** suggest that the government adhered to these criteria: upgraded flats are in planning areas[14] with older and smaller flats, and these flats are distributed relatively evenly across different geographical regions.

[12] See e.g. Phang (2015) and Teo and Kong (1997) for more details on HDB's upgrading programs.
[13] Part of our information on the MUP came from HDB's website. The relevant pages, however, have since been taken down due to the completion of the MUP. PDF versions of the relevant webpages are available on request.
[14] Planning areas are used by Singapore government agencies for urban planning and administrative purposes. Their boundaries differ somewhat from HDB town boundaries, but we use planning areas in this map as geocoded boundaries for HDB towns were not readily available.

The space-adding item (SAI) is an additional package on top of the standard package[15] of the MUP. SAI added about 6m^2 of floor area to existing flats, and the space was added by building additional columns next to existing blocks, then knocking down the connecting wall between the columns and existing flats when the columns were completed. If SAI were to proceed for a block, all flats within the block would receive the additional space, regardless of the original size of the flat and flat-type.

Once HDB offered MUP to a precinct, residents within a precinct would vote for or against the standard package and SAI separately, but the two polls would take place at around the same time. This voting process is important as part of the upgrading costs would be borne by the residents. The standard package would proceed for a precinct if at least 75% of the precinct's eligible citizen households voted in favour of it. The SAI would proceed for a block if the precinct it belongs to voted successfully for the standard package to proceed and at least 75% of the *block's* eligible citizen households voted for the SAI. In our study, we limit our sample to include only blocks for which the standard package was implemented, creating greater homogeneity within our sample. Since the MUP was offered to different precincts at different time periods, the time of polling and implementation varied across precincts. We are thus able to exploit cross-sectional and temporal variation in our identification strategy.

To ensure that households are not over-burdened by the upgrading costs, the government subsidized the costs for Singaporean citizens heavily, with owners of smaller flats (who typically have lower incomes) receiving a larger subsidy. Instalment plans for payment were also made available, and flat owners may also use their own savings for the payment. Here we highlight an important feature of bill payment which influences our empirical specification:

[15] The standard package of the MUP consists of upgrades to communal facilities at the precinct and block level, as well as improvements within individual flats. Examples of these upgrades include: multi-storey car parks, covered walkways, addition of ramps to improve wheelchair access, or playgrounds at the precinct level; upgrading of lifts to stop at every level at the block level; improvement of existing bathrooms and toilets within each flat.

Flat owners who sold their flat before they received the bill would not have to pay the upgrading cost; rather, buyers of the flat would have to foot the bill. For such sales transactions, we can expect buyers to negotiate a lower transaction price in view of the upgrading bill tab they would have to pick up later.

Despite subsidies from the government, 133 out of 243 blocks in our sample voted against SAI. This was due to at least three reasons. First, SAI would result in inconvenience, as the construction required for SAI would be carried out right next to existing flats. Potential negative externalities generated by SAI construction may deter the need for upgrading, especially for elderly flat owners. Second, flat owners have to pay quite a substantial amount if they opted for SAI. E.g., 1-3 room flat owners have to pay S$8,640 (after subsidy) if they opted for SAI[16]. In this instance, financially constrained owners would be more likely to vote against SAI. Third, some flat owners who voted against SAI could have a lower intrinsic demand for space. This variation in whether blocks voted in favour of SAI or not will be used to define our control and treatment groups.

3. Data

3.1. Data sources and variables

We obtain data for this study from three different sources. First, we download official statements of polling results for each block that was polled for the space-adding item (SAI) between Apr 2000 and Jul 2008 from the Singapore Government e-Gazette, an online repository of subsidiary legislation and gazettes. We use these statements to construct a novel dataset, containing SAI polling results at the block level and the polling date. We use the decision rules outlined in Section 2, as well as these polling results to construct dummy

[16] Cost figures are nominal and are relevant for precincts announced for MUP under Batch 20 onwards. The webpage from which we retrieved this information is no longer accessible online. PDF version of the webpage is available on request.

variables indicating if SAI was carried out. Second, we obtain the MUP/SAI billing date from HDB's online enquiry service. Third, we download administrative data on all HDB resale transactions for the period Jan 2000 – Aug 2015, from the Singapore government's data sharing website, https://data.gov.sg/. This provides us with data on the block, flat-type, floor/storey range, age, resale price and transaction month for each flat sold in this period. Resale price will be used as our main outcome variable.

We merge these three datasets, keep only precincts that voted for the standard package of MUP to proceed, and drop all precincts that were not polled for SAI between 2000 and 2008. We drop two precincts – Mei Ling and Kallang Basin – as these precincts do not have sufficient transactions in the period before the poll[17]. The combined dataset for our study thus includes only transactions in precincts which were polled for SAI between Jul 2000 and Jul 2008. In all, our dataset contains 18,817 transactions taking place across 48 precincts / 243 blocks.

3.2. Summary Statistics

Table 1a presents the overall summary statistics for our combined dataset. The majority of flats in our sample are old, with leases starting between 1967 and 1985, and relatively small, reflecting the government's stated policy of upgrading older and smaller flats. There is considerable variation in SAI polling results: the mean percentage of eligible citizen households in each block voting in favour of SAI is 69.67%, with a standard deviation of 15.42%. **Table 1b** breaks down the mean summary statistics by HDB town. The first two columns show that blocks polled for SAI in our sample are spread rather evenly across the island (see **Figure A1** for a map of HDB town locations). In addition, the mean flat type and lease commencement year of transacted flats does not vary dramatically across HDB towns.

[17] We need a sufficiently long period before the poll as we will include a placebo lead policy variable in our empirical specification to test statistically for whether our data violates the validity of the underlying assumption of our chosen methodology (i.e. difference-in-differences).

4. Identification Strategy

We analyze the effect of space-adding item (SAI) on resale prices and resale prices per square meter using a difference-in-differences (DID) strategy. The treatment group comprises resale transactions in blocks which have voted in favour of SAI (i.e. at least 75% of the block's eligible citizen households voted for the SAI), while the control group corresponds to resale transactions in blocks which have voted against SAI.

The DID design is valid only if the trends of resale prices of the treatment and control groups are the same in the absence of treatment. This assumption is often checked by comparing trends from both groups during the pre-treatment period. We plot in **Figure 3a** the unconditional monthly mean of log resale price from 60 months before the SAI polling month to 150 months after the SAI polling month, based on all blocks in our sample. It is obvious that the pre-treatment log resale price trends of the treatment and control groups are different. This brings up concerns as blocks where a low percentage of households voted for SAI are likely to be quite different from those where a high percentage voted for SAI.[18]

As the differences between the SAI blocks and non-SAI blocks are likely explained by observed location and household characteristics, we obtain the residual of log resale price after controlling for block fixed effects. If the pre-trend becomes similar after controlling for block fixed effects, we are more confident that the SAI and non-SAI blocks serve as comparable treatment and control groups. Results are plotted in **Figure 3b**, where there still exists a fair amount of deviation in price trend leading to the treatment. This suggests that the control and treatment groups are sufficiently different to invalidate the identifying assumption of the DiD

[18] The non-SAI blocks tend to have higher house price appreciations prior to the polling date for SAI. It could be that households who vote against further upgrading are also those that favor the existing structure of their units because of prior investments in maintenance and renovation.

strategy. For this reason, we further restrict our sample to a 10-percentage-point margin on either side of the 75% threshold and plot out similar residuals after controlling for block fixed effects in **Figure 3c**. In this case, the difference in pre-treatment trends between the treatment and control group largely disappears.[19] More importantly, it becomes apparent that blocks which voted for SAI experience a higher rate of price appreciation after the polling has been conducted.

5. Empirical Specifications

We further verify the validity of the DID design as part of the regression specification. To this end, we specify four periods: the benchmark period is from Jan 2000 to five months prior to the month in which households were polled for the space-adding item (SAI); the placebo-lead period is an interval of four months before the polling month – this will be used in our empirical specification to provide further evidence that our DID design is valid; the poll-bill period stretches from the polling month to the month before households were billed for SAI; and the post-bill period is from the billing month to Aug 2015. We restrict the placebo-lead period to an interval of four months to maximize the number of precincts we can keep in our sample.[20]

We estimate the effect of SAI on resale prices and resale prices per square meter using the following specification:

$$\begin{aligned} log(P_{ibt}) = \quad & \beta_{placebo-lead} SAI_b \times I_{placebo-lead,bt} + \beta_{poll-bill} SAI_b \\ & \times I_{poll-bil\ ,bt} \\ & + \beta_{post-bill} SAI_b \times I_{post-bill,bt} + X_{ib} + \mu_b + \tau_t + \varepsilon_{ibt} \end{aligned} \quad \textbf{(1)}$$

[19] We do not plot the price trend using more restricted sample in the 70%-80% range because its small sample size prevents us from tracking price changes continuously.
[20] The polling month in some precincts occurs close to the start of our sample.

where P_{ibt} is the nominal resale price or resale price per square meter for transaction of flat *i* in block b and month-year *t*; SAI_b is a dummy for whether the block voted in favour of SAI; $I_{placebo-lead,bt}$, $I_{poll-bill,bt}$, and $I_{post-bill,bt}$ are dummies for whether the transaction occurred in the placebo-lead, between polling and billing and post-billing periods respectively; X_{ib} captures transaction-level information on flat type and floor level range; μ_b and τ_t are block fixed effects and year-month fixed effects. The standard errors in all regression analyses are clustered at the precinct level.

The key parameters of interest are $\beta_{placebo-lea}$, $\beta_{poll-bill}$, and $\beta_{post-bill}$. $\beta_{placebo-lead}$ estimates the average percentage difference in the resale prices between the treatment and the control group relative to the benchmark period. If our DID specification is valid, we would expect $\beta_{placebo-lea}$, which serves as a pseudo treatment effect, to be insignificantly different from zero. $\beta_{poll-bill}$ and $\beta_{post-bill}$ measure the average percentage difference in resale prices between the treatment and the control group (relative to the benchmark period) during the period between polling and billing, and the period after billing respectively. We distinguish between $\beta_{poll-bill}$ and $\beta_{post-bill}$ for two reasons. First, the construction period falls between polling and billing dates, during which prices may reflect construction externalities. Second, flat owners who sold their flat before they received the bill do not have to pay the upgrading cost; rather, buyers of the flat would have to foot the bill. Flat owners, however, had to pick up the upgrading tab if they sold their flats after they were billed. As such, we expect $\beta_{post-bill}$ to be larger than $\beta_{poll-bil}$. While we expect $\beta_{post-bill}$ to be positive, $\beta_{poll-bil}$ could be close to zero or even negative due to buyers' need to subsequently pay for the upgrading cost and endure any inconveniences caused by the ongoing construction for upgrading. [21]

[21] We do not include a period for post-construction as we do not have precise information on when upgrading for each precinct was completed.

Our ability to interpret $\beta_{poll-bill}$ and $\beta_{post-bil}$ as treatment effects could be hindered by unobserved heterogeneity between treatment and control groups. These parameters could be biased upwards if households that voted in favour of SAI have unobserved characteristics that are positively correlated with their decision to vote for SAI as well as the outcome variable. For example, households who voted for SAI may treat their flat more as an investment rather than consumption good, therefore choosing to vote for SAI and also driving a harder bargain at the point of sale.

To reduce the influence of self-selection on the estimated policy effects, we will also estimate **Eq. (1)** based on 2 restricted samples: the first admits only blocks that have SAI voting percentages between 65% and 85% (10 percentage points above and below the 75% threshold), the second includes blocks that have SAI voting percentages between 70% and 80% (5 percentage points above and below the 75% threshold). If there is indeed a self-selection problem, we would expect $\beta_{poll-bil}$ and $\beta_{post-bill}$ to fall as we restrict the sample to narrower margins around the threshold. This is also what we have documented in our results.

Since the main aim of our paper is to perform a model-free estimation of the hedonic price function of housing space, we also interact $I_{post-bill,bt}$ with dummies that represent different categories of a flat's original floor area (before the implementation of SAI). Heterogenous estimates from these specifications are also compared with those from specifications that examine heterogeneity of effects by parametric functions of area and flat-types.

6. Main Results

In this section, we first present results for resale price, then resale price per square meter. **Table 2** captures the average effect of the space-adding item (SAI) on resale price, based on the estimation of **Eq. (1)**. Columns (1) to (3) show the results from gradually adding flat-type fixed effects, floor level range fixed effects, lease commencement year fixed effects and precinct fixed effects to the full sample regression. Column (4) further controls for block fixed effects. Columns (5) and (6) show the results with restricted samples (blocks that have SAI voting percentages between 65% and 85%; and blocks that have SAI voting percentages between 70% and 80% respectively) to ensure more comparable treatment and control groups.

We consider estimates reported in Column (4) to (6) as the most conservative as they come with the most extensive set of controls. In all three samples, the coefficient estimates on $SAI_b \times I_{placebo-lead,bt}$ are statistically insignificant, suggesting that there are no differences in the resale price trend between the treatment and the control group (relative to the benchmark period) in the immediate four-month period prior to the poll for SAI. The coefficient estimates on $SAI_b \times I_{poll-bil\ ,bt}$ and $SAI_b \times I_{post-bill,bt}$ are positive and fall in magnitude as we restrict the sample to narrower margins around the 75% voting threshold, though the fall when we move from 10% to 5% margins around the threshold is negligible. This is in line with our expectation that the self-selection of households into the SAI package can be addressed by restricting the sample.

As the sample becomes more restricted around the threshold, the poll-bill difference in the resale price trend between the treatment and the control group falls from 3.29% to 0.30%. Similarly, the post-bill difference falls from 12.63% to 6.96%. While the coefficient estimates on $SAI_b \times I_{poll-bill,bt}$ become statistically insignificant once the sample is restricted, the coefficient estimates on $SAI_b \times I_{post-bill,bt}$ remain statistically significant throughout. This suggests that the price appreciation following the space addition mainly took place after the billing date (which occurs after construction was completed).

The estimates above indicate the average treatment-on-treated effect of SAI. To document the extent to which the price appreciation varied with the original size of the unit, we further interact the treatment effect with original housing space in **Table 3**. Columns (1) to (3) impose a linear functional form while Column (4) to (6) impose a quadratic functional form. The results are consistent across all specifications: additional space led to an increase in total house value, and the extent of price appreciation decreased with original housing size. **Table 4** presents results from further relaxing the earlier functional form restrictions by allowing the treatment effect to vary with area categories represented by dummies. We show that our findings from **Table 3** still hold in general. For example, the space-adding program increased the price of units originally smaller than 55 square meters by 15.97% (a nominal price increase of S$27,500[22]). At the same time, the price appreciation was small and statistically insignificant for units originally larger than 75 square meters. Given the positive correlation between house size and flat-types, we also document heterogeneity in treatment effects by flat-types in **Table 5**. We see the largest effects in 2-room flats, and the size of these effects falls as the number of rooms increase. In all, our model-free estimation suggests that the hedonic price function of housing space appears to be concave.

Next, we discuss the estimated effect of SAI on resale price per square meter, which captures the change in average price per unit of housing space. Results in **Tables 6**, **7**, and **8** are generally consistent with an inverted U-shape curve for average price per unit of housing space. For example, in column (3) of **Table 7**, the change in average price per unit of housing space was 10.46% for flats with original housing space less than 55 square meters, close to 0% for flats with original housing space between 55 and 65 square meters and -9.00% for flats with original housing space more than 85 square meters. These results suggest that total house price appreciation can be attributed to the combined effect of a change in housing space and the

[22] S$27,500 is based on 16% of the mean nominal price of treated flats in our benchmark period.

average price per unit housing space. To illustrate, for small units less than 55 square meters, adding 6 square meters of space contributed to a rise in per square meter price of 10.46%. Together with the added space, this led to an overall price appreciation of 16% documented earlier.

Lastly, we compare the marginal price of housing space which we estimate using the quasi-experiment, to estimates we obtain from a standard hedonic regression based on all flats transacted before the SAI poll (see **Tables 9a** and **9b** for estimates from the standard hedonic regression). We compute marginal effects from all the different specifications and present them in **Table 10**. Based on regressions with log resale price as the dependent variable, the "average" marginal effect estimated using the quasi-experiment is slightly smaller than that from the standard hedonic regression (see Panel A: 1.25% versus 1.16%), and the estimates from the quasi-experiment show a larger variation in magnitudes across the different categories of housing space (see **Figure 4** for a visual representation). In addition, the shape of the curve obtained if we plot average price per square meter against housing space seems to differ across the traditional hedonic and quasi-experiment methods (compare Column (4) in **Table 9b** and Column (3) in **Table 7**). This could possibly be driven by the existence of omitted variables or misspecification of the functional form.

7. Conclusion

Estimating the value of any housing attribute with a standard hedonic regression often suffers from the problems of functional form misspecifications and omitted variable bias. To address these problems, we perform a model-free estimation of the hedonic price of housing space, by exploiting a unique quasi-experiment in Singapore that added a uniform amount of space ($6m^2$) to existing housing units, regardless of their original size. This space-adding project was part of a large scale urban renewal and housing upgrading policy in Singapore, and was carried out only if sufficient residents within a high-rise building vote in favour of it (i.e. at least 75% of households must vote in favour of it). We use a difference-in-differences (DiD) strategy on a restricted sample around the voting cut-off, to account for unobserved heterogeneity between the treatment and control groups that could invalidate the DiD identifying assumption.

We find that the additional space increased the resale price of a housing unit by 7% on average, and the heterogeneity of price appreciation across the range of original housing size is consistent with a concave hedonic price function for space. We also find that the total house price appreciation can be attributed to a combined effect of a change in housing space together with a different level of average price for per unit housing space. Comparison of the estimates of marginal price of housing space obtained from the quasi-experiment and standard hedonic regression show that the "average" marginal effect estimated using the quasi-experiment is slightly smaller than that from the standard hedonic regression, and the estimates from the quasi-experiment show a larger variation in magnitudes across the different categories of housing space. In addition, the shape of the curve obtained if we plot average price per square meter against housing space seems to differ across the traditional hedonic and quasi-experiment methods.

In all, this paper contributes to the scarce literature that looks specifically at the role of housing space in determining the value of a housing unit. It also contributes to the literature that combines quasi-experiments with the hedonic model to address the concern of omitted variables, and efforts to relax functional form restrictions on the hedonic price function. The unique setting allows for comparing the differencing-produced implicit prices to those obtained from hedonic regressions. The evidence adds to our understanding of the effectiveness of these two different approaches in calculating the housing price index. Lastly, it is related to the literature on housing upgrading and remodelling, by providing evidence on the potential benefits of upgrading.

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Table 1a Summary Statistics

Variable	N	Mean	Std. Dev.	Min	Max	Summary Level
Nominal Resale Price (S$)[1]	18,817	267,628	129,045	55,000	985,000	Transaction
Nominal Resale Price Per Square Meter (S$)	18,817	3,411	1,261	1,053	8,308	Transaction
Floor Area (Square Meters) [2]	18817	76.38	20.51	40.00	171.00	Transaction
2-room	137	42.95	2.89	40.00	57.00	Transaction
3-room	12,404	64.54	6.58	52.00	83.00	Transaction
4-room	3,684	87.07	5.88	77.00	132.00	Transaction
5-room and Bigger	2,592	119.59	6.09	111.00	171.00	Transaction
Less than 55 square meters	620	51.27	4.66	40.00	54.00	Transaction
55 square meters to 65 square meters	5,358	59.33	0.98	57.00	63.00	Transaction
65 square meters to 75 square meters	5,695	67.69	1.01	65.00	72.00	Transaction
75 square meters to 85 square meters	2,731	81.83	1.22	77.00	84.00	Transaction
More than 85 square meters	4,413	108.42	14.25	89.00	171.00	Transaction
Flat Type (# of Rooms) [3]	18,817	3.47	0.74	2	6	Transaction
Lease Commencement Year	18,817	1976.94	3.26	1967	1985	Transaction
% Voted for SAI / Block	243	69.67	15.42	29.47	94.62	Block

[1] Resale price refers to price of flats sold on the open market, rather than direct sales from the Government.
[2] Floor area is based on quantity before implementation of SAI.
[3] Flat type takes on values 2 – 6, with 2-5 referring to a 2-5-room flat and 6 referring to an executive flat (a flat larger than a 5-room flat, but usually situated within the same block with other 4- and 5-room flats).

Table 1b Summary Statistics (by HDB Town)

Town	No. of Transactions	No. of Blocks Polled for SAI	Mean Nominal Resale Price (S$)	Mean Flat Type[1]	Mean Lease Commence Year	% of Blocks Voting YES
Ang Mo Kio	2,236	26	250,968	3.35	1979.0	0.73
Bedok	3,681	48	269,614	3.58	1978.4	0.21
Bukit Merah	1,734	24	279,546	3.41	1976.2	0.42
Central Area	90	2	290,438	3.07	1982.1	0.50
Choa Chu Kang	489	8	221,975	3.87	1978.6	0.25
Clementi	1,401	16	262,484	3.30	1979.3	0.00
Geylang	971	12	232,486	3.25	1978.1	0.67
Jurong West	184	9	282,135	5.00	1976.0	0.11
Kallang/Whampoa	1,528	22	260,680	3.45	1973.9	0.55
Marine Parade	1,614	25	355,201	3.73	1975.0	0.64
Queenstown	2,446	26	289,128	3.37	1973.9	0.65
Toa Payoh	1,621	19	238,557	3.40	1975.7	0.74
Woodlands	822	6	184,920	3.30	1980.8	0.00
Total	18,817	243	267,628	3.47	1976.9	0.45

[1] Flat type takes on values 2 – 6, with 2-5 referring to a 2-5-room flat and 6 referring to an Executive flat (a flat larger than a 5-room flat, but usually situated within the same block with other 4- and 5-room flats).

Table 2: Impact of Space-Adding-Item (SAI) on HDB Resale Prices
Dependent Variable: Log Resale Price

	Full Sample	Full Sample	Full Sample	Full Sample	65%-85%	70%-80%
	(1)	(2)	(3)	(4)	(5)	(6)
SAI	0.0059	-0.0380	-0.0411**	-	-	-
	(0.042)	(0.023)	(0.017)	-	-	-
SAI × Placebo-Lead Period	-0.0459**	-0.0267*	-0.0142	-0.0114	-0.0033	0.0113
	(0.018)	(0.015)	(0.016)	(0.015)	(0.017)	(0.022)
SAI × Post-Polling but Pre-Billing Period	0.0018	0.0147	0.0251*	0.0329**	0.0141	0.0030
	(0.022)	(0.016)	(0.015)	(0.014)	(0.017)	(0.015)
SAI × Post-Billing Period	0.0744**	0.0930***	0.1160***	0.1263***	0.0762***	0.0696***
	(0.029)	(0.020)	(0.020)	(0.021)	(0.021)	(0.020)
Month × Year Fixed Effects	YES	YES	YES	YES	YES	YES
Flat Type Fixed Effects	YES	YES	YES	YES	YES	YES
Floor Level Range Fixed Effects	YES	YES	YES	YES	YES	YES
Lease Commence Year Fixed Effects	NO	YES	YES	NO	NO	NO
Precinct Fixed Effects	NO	NO	YES	NO	NO	NO
Block Fixed Effects	NO	NO	NO	YES	YES	YES
Observations	18,817	18,817	18,817	18,817	10,055	5,144
R-squared	0.865	0.893	0.943	0.949	0.947	0.951

[1] Standard errors clustered at the precinct level are reported in parentheses. ***, **, * represent statistical significance at 1, 5, and 10 percent level respectively.
[2] The placebo-lead period is an interval of four months before the polling month – this is used in our empirical specification to provide further evidence that our DID design is valid. The poll-bill period stretches from the polling month to the month before households were billed for SAI. The post-bill period is from the billing month to Aug 2015. The omitted category is the benchmark period which is from Jan 2000 to five months prior to the month in which households were polled for SAI.

Table 3: Impact of Space-Adding-Item on HDB Resale Prices (Heterogeneous Effects by Parametric Functions of Floor Area)
Dependent Variable: Log Resale Price

	Full Sample	65%-85%	70%-80%	Full Sample	65%-85%	70%-80%
	(1)	(2)	(3)	(4)	(5)	(6)
SAI × Placebo-Lead Period	-0.0101	-0.0020	0.0117	-0.0086	-0.0002	0.0123
	(0.015)	(0.016)	(0.020)	(0.014)	(0.016)	(0.020)
SAI × Post-Polling but Pre-Billing Period	0.0345**	0.0154	0.0030	0.0370***	0.0182	0.0045
	(0.014)	(0.016)	(0.013)	(0.013)	(0.015)	(0.013)
SAI × Post-Billing Period	0.2289***	0.2270***	0.2469***	0.5325***	0.5518***	0.4070***
	(0.043)	(0.048)	(0.062)	(0.141)	(0.133)	(0.128)
SAI × Post-Billing Period × Area	-0.0015***	-0.0022***	-0.0025***	-0.0091***	-0.0102***	-0.0065**
	(0.000)	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)
SAI × Post-Billing Period × Area Squared	-	-	-	4.41e-05**	4.65e-05***	2.29e-05
	-	-	-	(1.78e-05)	(1.6e-05)	(1.53e-05)
Month × Year Fixed Effects	YES	YES	YES	YES	YES	YES
Flat Type Fixed Effects	YES	YES	YES	YES	YES	YES
Floor Level Range Fixed Effects	YES	YES	YES	YES	YES	YES
Block Fixed Effects	YES	YES	YES	YES	YES	YES
Observations	18,817	10,055	5,144	18,817	10,055	5,144
R-squared	0.949	0.948	0.952	0.950	0.948	0.952

[1] Standard errors clustered at the precinct level are reported in parentheses. ***, **, * represent statistical significance at 1, 5, and 10 percent level respectively.
[2] Floor area is based on quantity before implementation of SAI.

Table 4: Impact of Space-Adding-Item on HDB Resale Prices (Heterogeneous Effects by Floor Area Categories)
Dependent Variable: Log Resale Price

	Full Sample	65%-85%	70%-80%
	(1)	(2)	(3)
SAI × Placebo-Lead Period	-0.0098	-0.0012	0.0108
	(0.014)	(0.016)	(0.021)
SAI × Post-Polling but Pre-Billing Period	0.0345**	0.0162	0.0025
	(0.013)	(0.016)	(0.013)
SAI × Post-Billing Period × (Area < 55 SQM)	0.2490***	0.2270***	0.1597***
	(0.029)	(0.040)	(0.026)
SAI × Post-Billing Period × (55 SQM ≤ Area <65 SQM)	0.1271***	0.0855***	0.0871***
	(0.024)	(0.025)	(0.023)
SAI × Post-Billing Period × (65 SQM ≤ Area < 75 SQM)	0.1513***	0.1036***	0.0956***
	(0.024)	(0.025)	(0.026)
SAI × Post-Billing Period × (75 SQM ≤ Area < 85 SQM)	0.0802***	0.0317	0.0352
	(0.029)	(0.029)	(0.039)
SAI × Post-Billing Period × (85 SQM ≤ Area)	0.0590**	-0.0083	-0.0339
	(0.025)	(0.024)	(0.033)
Month × Year Fixed Effects	YES	YES	YES
Flat Type Fixed Effects	YES	YES	YES
Floor Level Range Fixed Effects	YES	YES	YES
Block Fixed Effects	YES	YES	YES
Observations	18,817	10,055	5,144
R-squared	0.950	0.949	0.952

[1] Standard errors clustered at the precinct level are reported in parentheses. ***, **, * represent statistical significance at 1, 5, and 10 percent level respectively.
[2] Floor area is based on quantity before implementation of SAI.

Table 5: Impact of Space-Adding-Item on HDB Resale Prices (Heterogeneous Effects by Flat Type)
Dependent Variable: Log Resale Price

	Full Sample	65%-85%	70%-80%
	(1)	(2)	(3)
SAI × Placebo-Lead Period	-0.0109	-0.0028	0.0090
	(0.014)	(0.016)	(0.020)
SAI × Post-Polling but Pre-Billing Period	0.0341**	0.0142	-0.0032
	(0.013)	(0.015)	(0.013)
SAI × Post-Billing Period × 2-Room-Flat	0.4393***	0.4597***	0.3054***
	(0.051)	(0.040)	(0.030)
SAI × Post-Billing Period × 3-Room-Flat	0.1426***	0.1020***	0.0979***
	(0.021)	(0.022)	(0.021)
SAI × Post-Billing Period × 4-Room-Flat	0.0405*	-0.0122	-0.0256
	(0.022)	(0.024)	(0.023)
SAI × Post-Billing Period × 5-Room-Flat or bigger	0.0517	-0.0236	-0.0813
	(0.037)	(0.036)	(0.052)
Month × Year Fixed Effects	YES	YES	YES
Flat Type Fixed Effects	YES	YES	YES
Floor Level Range Fixed Effects	YES	YES	YES
Block Fixed Effects	YES	YES	YES
Observations	18,817	10,055	5,144
R-squared	0.951	0.950	0.954

[1] Standard errors clustered at the precinct level are reported in parentheses. ***, **, * represent statistical significance at 1, 5, and 10 percent level respectively.

Table 6: Impact of Space-Adding-Item on HDB Resale Prices (Heterogeneous Effects by Parametric Functions of Floor Area)
Dependent Variable: Log Resale Price Per Square Meter

	Full Sample	65%-85%	70%-80%	Full Sample	65%-85%	70%-80%
	(1)	(2)	(3)	(4)	(5)	(6)
SAI × Placebo-Lead Period	-0.0128	-0.0069	0.0040	-0.0109	-0.0046	0.0052
	(0.013)	(0.014)	(0.015)	(0.013)	(0.014)	(0.015)
SAI × Post-Polling but Pre-Billing Period	0.0381***	0.0193	0.0072	0.0413***	0.0231	0.0103
	(0.013)	(0.015)	(0.012)	(0.012)	(0.014)	(0.012)
SAI × Post-Billing Period	0.2180***	0.1827***	0.1741***	0.6040***	0.6117***	0.5060***
	(0.045)	(0.046)	(0.050)	(0.104)	(0.097)	(0.087)
SAI × Post-Billing Period × Area	-0.0026***	-0.0027***	-0.0026***	-0.0122***	-0.0133***	-0.0108***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
SAI × Post-Billing Period × Area Squared	-	-	-	5.61e-05***	6.14e-05***	4.75e-05***
	-	-	-	(1.19e-05)	(1.15e-05)	(1.11e-05)
Month × Year Fixed Effects	YES	YES	YES	YES	YES	YES
Flat Type Fixed Effects	YES	YES	YES	YES	YES	YES
Floor Level Range Fixed Effects	YES	YES	YES	YES	YES	YES
Block Fixed Effects	YES	YES	YES	YES	YES	YES
Observations	18,817	10,055	5,144	18,817	10,055	5,144
R-squared	0.936	0.941	0.948	0.937	0.942	0.949

[1] Standard errors clustered at the precinct level are reported in parentheses. ***, **, * represent statistical significance at 1, 5, and 10 percent level respectively.
[2] Floor area is based on quantity before implementation of SAI.

Table 7: Impact of Space-Adding-Item on HDB Resale Prices (Heterogeneous Effects by Floor Area Categories)
Dependent Variable: Log Resale Price Per Square Meter

	Full Sample	65%-85%	70%-80%
	(1)	(2)	(3)
SAI × Placebo-Lead Period	-0.0107	-0.0052	0.0032
	(0.013)	(0.014)	(0.016)
SAI × Post-Polling but Pre-Billing Period	0.0411***	0.0216	0.0073
	(0.012)	(0.014)	(0.013)
SAI × Post-Billing Period × (Area < 55 SQM)	0.2004***	0.1603***	0.1046***
	(0.021)	(0.027)	(0.025)
SAI × Post-Billing Period × (55 SQM ≤ Area <65 SQM)	0.0619**	0.0216	0.0166
	(0.023)	(0.025)	(0.022)
SAI × Post-Billing Period × (65 SQM ≤ Area < 75 SQM)	0.0412**	0.0115	0.0102
	(0.020)	(0.021)	(0.022)
SAI × Post-Billing Period × (75 SQM ≤ Area < 85 SQM)	-0.0231	-0.0695***	-0.0778***
	(0.023)	(0.024)	(0.023)
SAI × Post-Billing Period × (85 SQM ≤ Area)	-0.0299	-0.0808***	-0.0900***
	(0.022)	(0.024)	(0.031)
Month × Year Fixed Effects	YES	YES	YES
Flat Type Fixed Effects	YES	YES	YES
Floor Level Range Fixed Effects	YES	YES	YES
Block Fixed Effects	YES	YES	YES
Observations	18,817	10,055	5,144
R-squared	0.937	0.942	0.949

[1] Standard errors clustered at the precinct level are reported in parentheses. ***, **, * represent statistical significance at 1, 5, and 10 percent level respectively.
[2] Floor area is based on quantity before implementation of SAI.

Table 8: Impact of Space-Adding-Item on HDB Resale Prices (Heterogeneous Effects by Flat Type)
Dependent Variable: Log Resale Price Per Square Meter

	Full Sample	65%-85%	70%-80%
	(1)	(2)	(3)
SAI × Placebo-Lead Period	-0.0146	-0.0080	0.0019
	(0.014)	(0.015)	(0.016)
SAI × Post-Polling but Pre-Billing Period	0.0362***	0.0181	0.0027
	(0.012)	(0.014)	(0.012)
SAI × Post-Billing Period × 2-Room-Flat	0.3073***	0.3228***	0.1701***
	(0.046)	(0.040)	(0.029)
SAI × Post-Billing Period × 3-Room-Flat	0.0544**	0.0163	0.0101
	(0.021)	(0.021)	(0.021)
SAI × Post-Billing Period × 4-Room-Flat	-0.0295	-0.0813***	-0.0889***
	(0.022)	(0.023)	(0.023)
SAI × Post-Billing Period × 5-Room-Flat or bigger	-0.0361	-0.0702**	-0.1141**
	(0.029)	(0.034)	(0.052)
Month × Year Fixed Effects	YES	YES	YES
Flat Type Fixed Effects	YES	YES	YES
Floor Level Range Fixed Effects	YES	YES	YES
Block Fixed Effects	YES	YES	YES
Observations	18,817	10,055	5,144
R-squared	0.937	0.942	0.949

[1] Standard errors clustered at the precinct level are reported in parentheses. ***, **, * represent statistical significance at 1, 5, and 10 percent level respectively.

Table 9a: Hedonic Regressions

Dependent Variable	Log Resale Price			Log Resale Price Per Square Meter		
	(1)	(2)	(3)	(4)	(5)	(6)
Original Floor Area	0.0125***	0.0268***	0.0698***	-0.0008	0.0041	0.0358
	(0.001)	(0.004)	(0.025)	(0.001)	(0.004)	(0.025)
Original Floor Area Squared	-	-0.0001***	-0.0006**	-	-3.15e-05	-0.0004
	-	(0.000)	(0.000)	-	(0.000)	(0.000)
Original Floor Area Cube	-	-	1.61e-06*	-	-	1.19e-06
	-	-	(0.000)	-	-	(0.000)
Month × Year Fixed Effects	YES	YES	YES	YES	YES	YES
Flat Type Fixed Effects	YES	YES	YES	YES	YES	YES
Floor Level Range Fixed Effects	YES	YES	YES	YES	YES	YES
Block Fixed Effects	YES	YES	YES	YES	YES	YES
Observations	5,992	5,992	5,992	5,992	5,992	5,992
R-squared	0.944	0.946	0.946	0.843	0.843	0.844

[1] Standard errors clustered at the precinct level are reported in parentheses. ***, **, * represent statistical significance at 1, 5, and 10 percent level respectively. Sample is based on periods prior to the polling of SAI.

[2] Floor area is based on quantity before implementation of SAI.

Table 9b: Hedonic Regressions

Dependent Variable	Log Resale Price		Log Resale Price Per Square Meter	
	(1)	(2)	(3)	(4)
Area < 55 SQM	-0.7658***	-	-0.0320	-
	(0.051)	-	(0.040)	-
55 SQM ≤ Area <65 SQM	-0.5673***	-	-0.0438	-
	(0.025)	-	(0.029)	-
65 SQM ≤ Area < 75 SQM	-0.4135***	-	-0.0547***	-
	(0.018)	-	(0.019)	-
75 SQM ≤ Area < 85 SQM [2]	-0.1711***	-	-0.0045	-
	(0.017)	-	(0.022)	-
2-Room-Flat	-	-1.0759***	-	-0.0917*
	-	(0.041)	-	(0.054)
3-Room-Flat	-	-0.6592***	-	0.0150
	-	(0.032)	-	(0.049)
4-Room-Flat [2]	-	-0.2878***	-	0.0965*
	-	(0.037)	-	(0.055)
Month × Year Fixed Effects	YES	YES	YES	YES
Flat Type Fixed Effects	YES	NO	YES	NO
Floor Level Range Fixed Effects	YES	YES	YES	YES
Block Fixed Effects	YES	YES	YES	YES
Observations	5,992	5,992	5,992	5,992
R-squared	0.939	0.882	0.838	0.738

[1] Standard errors clustered at the precinct level are reported in parentheses. ***, **, * represent statistical significance at 1, 5, and 10 percent level respectively. Sample is based on periods prior to the polling of SAI.

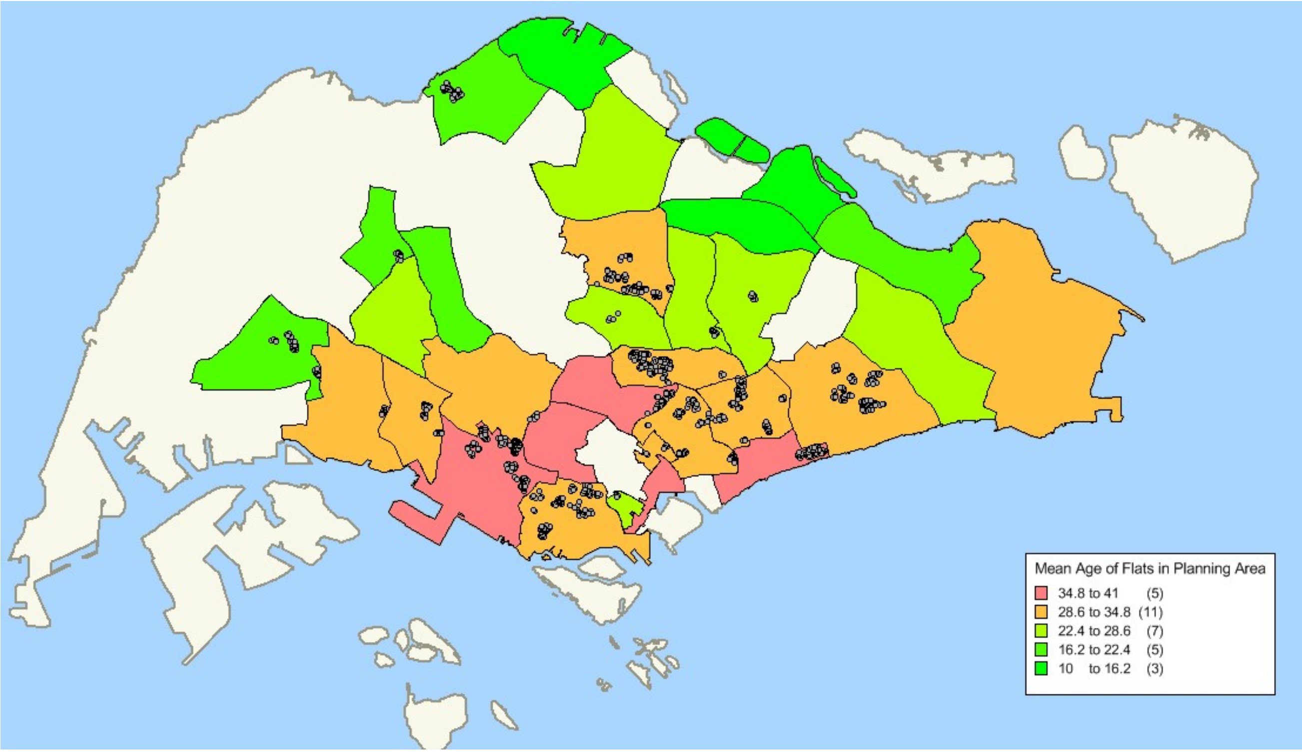
[2] Floor area is based on quantity before implementation of SAI.

[3] Suppressed category for regression specifications estimated in Col (1) and (3) is 85 SQM ≤ Area. Suppressed category for regression specifications estimated in Col (2) and (4) is 5-room-flat or bigger.

Table 10: Summary of the Marginal Effect of Housing Space

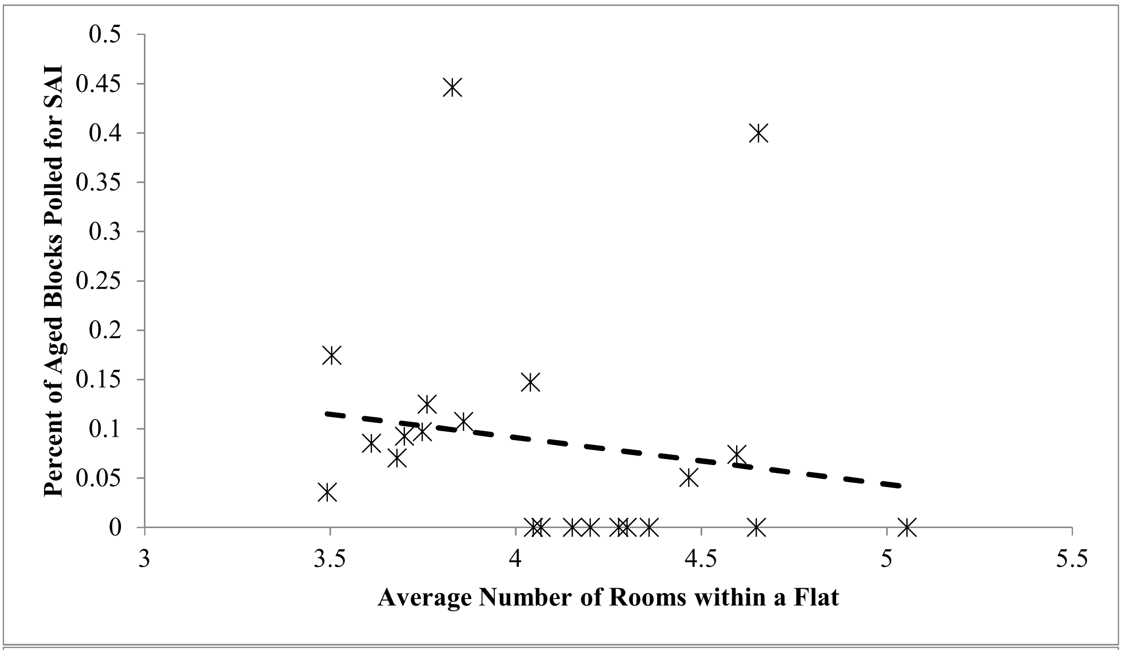
	(1)	(2)	(3)	(4)	(5)
Space Categories	Area < 55 SQM	55 SQM ≤ Area <65 SQM	65 SQM ≤ Area < 75 SQM	75 SQM ≤ Area < 85 SQM	85 SQM ≤ Area
Average Space within Each Category	51.27	59.33	67.69	81.83	108.42
Panel A: Log Resale Price					
Hedonic Estimates					
Linear Function of Space [1]	1.25%	1.25%	1.25%	1.25%	1.25%
Quadratic Function of Space [1]	1.65%	1.49%	1.33%	1.04%	0.51%
Cubic Function of Space [1]	2.10%	1.56%	1.07%	0.39%	-0.35%
Dummies of Space Categories [2]	2.46%	1.84%	1.71%	0.64%	-
Identified around the Voting Cut-off in DID					
Constant [3]	1.16%	1.16%	1.16%	1.16%	1.16%
Linear Function of Space [4]	1.98%	1.64%	1.29%	0.71%	-0.40%
Quadratic Function of Space [4]	2.23%	1.70%	1.20%	0.47%	-0.48%
Dummies of Space Categories [5]	2.66%	1.45%	1.59%	0.59%	-0.57%
Panel B: Log Resale Price Per Square Meter					
Identified around the Voting Cut-off in DID					
Linear Function of Space [6]	0.68%	0.33%	-0.03%	-0.64%	-1.80%
Quadratic Function of Space [6]	1.29%	0.54%	-0.12%	-0.99%	-1.78%
Dummies of Space Categories [7]	1.74%	0.28%	0.17%	-1.30%	-1.50%

[1] Based on estimates in Table 9a.
[2] Based on estimates in Table 9b.
[3] Based on estimates in Table 2.
[4] Based on estimates in Table 3.
[5] Based on estimates in Table 4.
[6] Based on estimates in Table 6.
[7] Based on estimates in Table 7.



Source: Data on upgrading are from HDB's online enquiry service; data on age of flats are from http://www.teoalida.com/singapore/hdbdatabase/

Figure 1: Geographic Distribution of Upgraded Blocks and Mean Age of Flats (as of 2015) within each Planning Area
*Each dot represents a block of flats that was chosen for the Main Upgrading Programme.



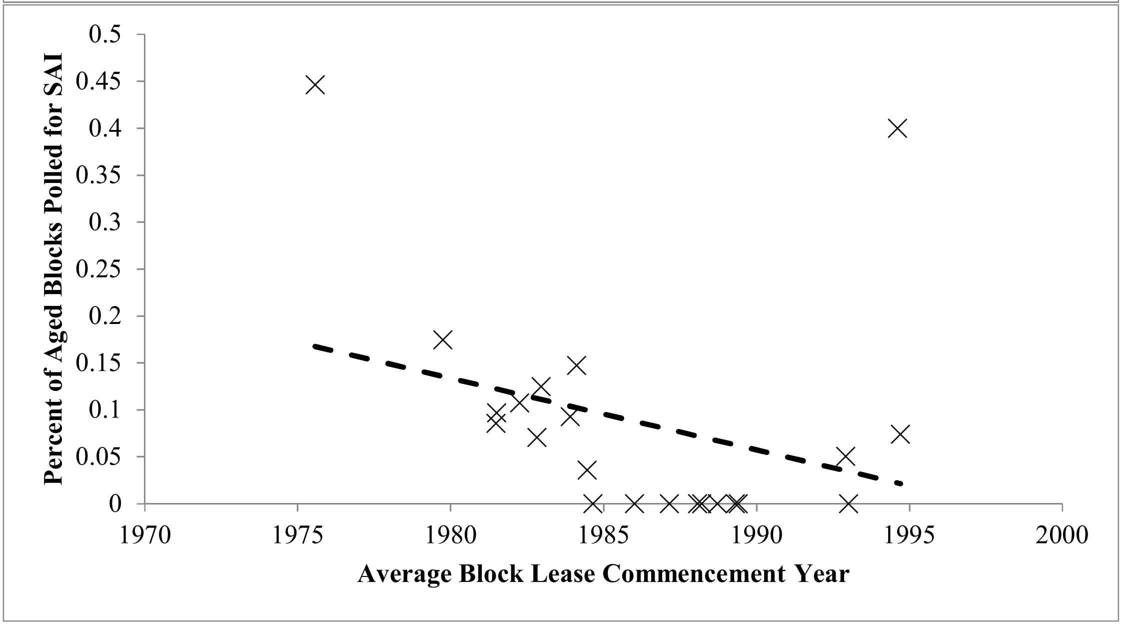


Figure 2: Percent of Aged Blocks (Built Before 1985) Polled for SAI within a HDB Town

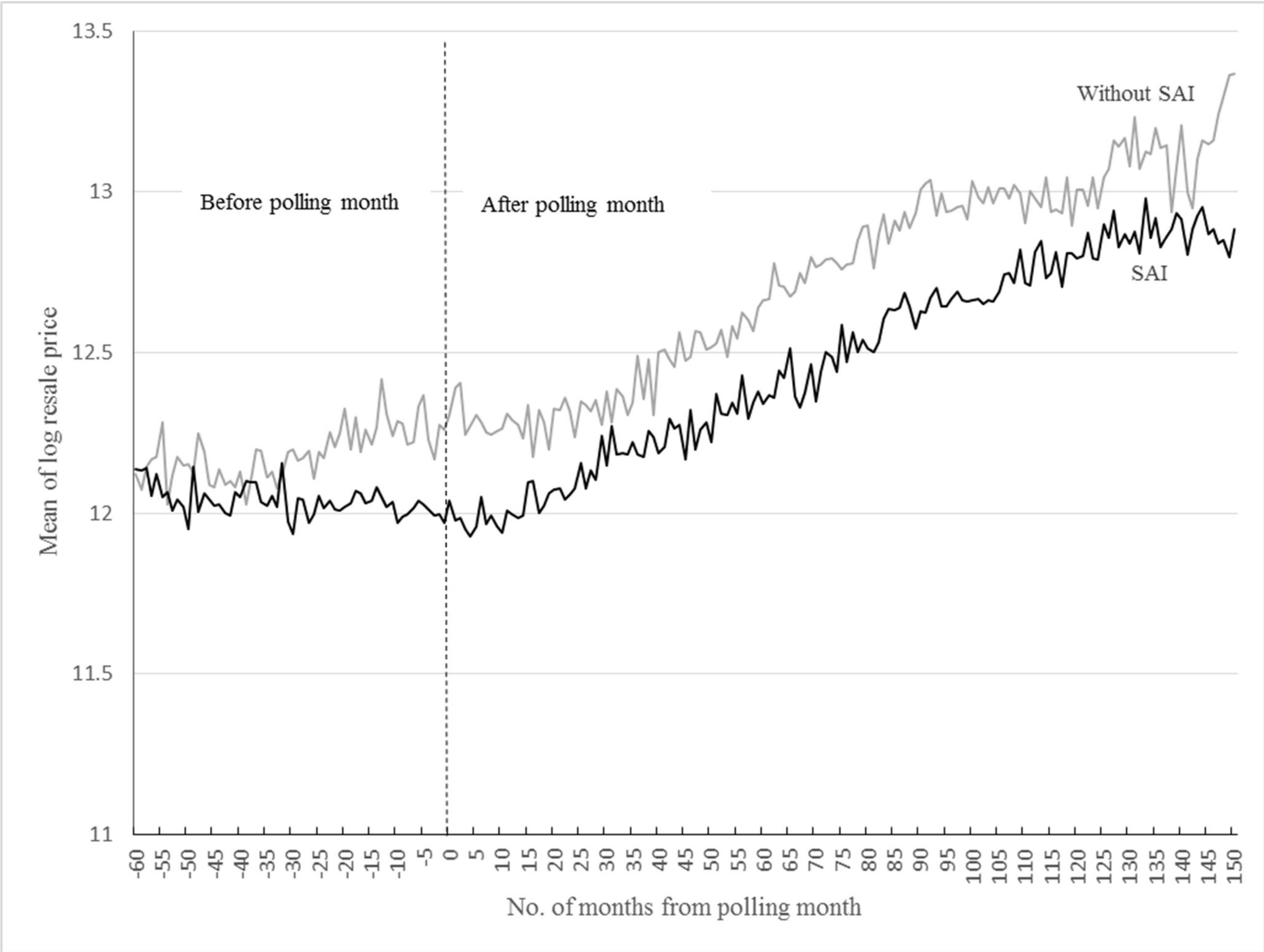


Figure 3a: Unconditional monthly mean of log resale price

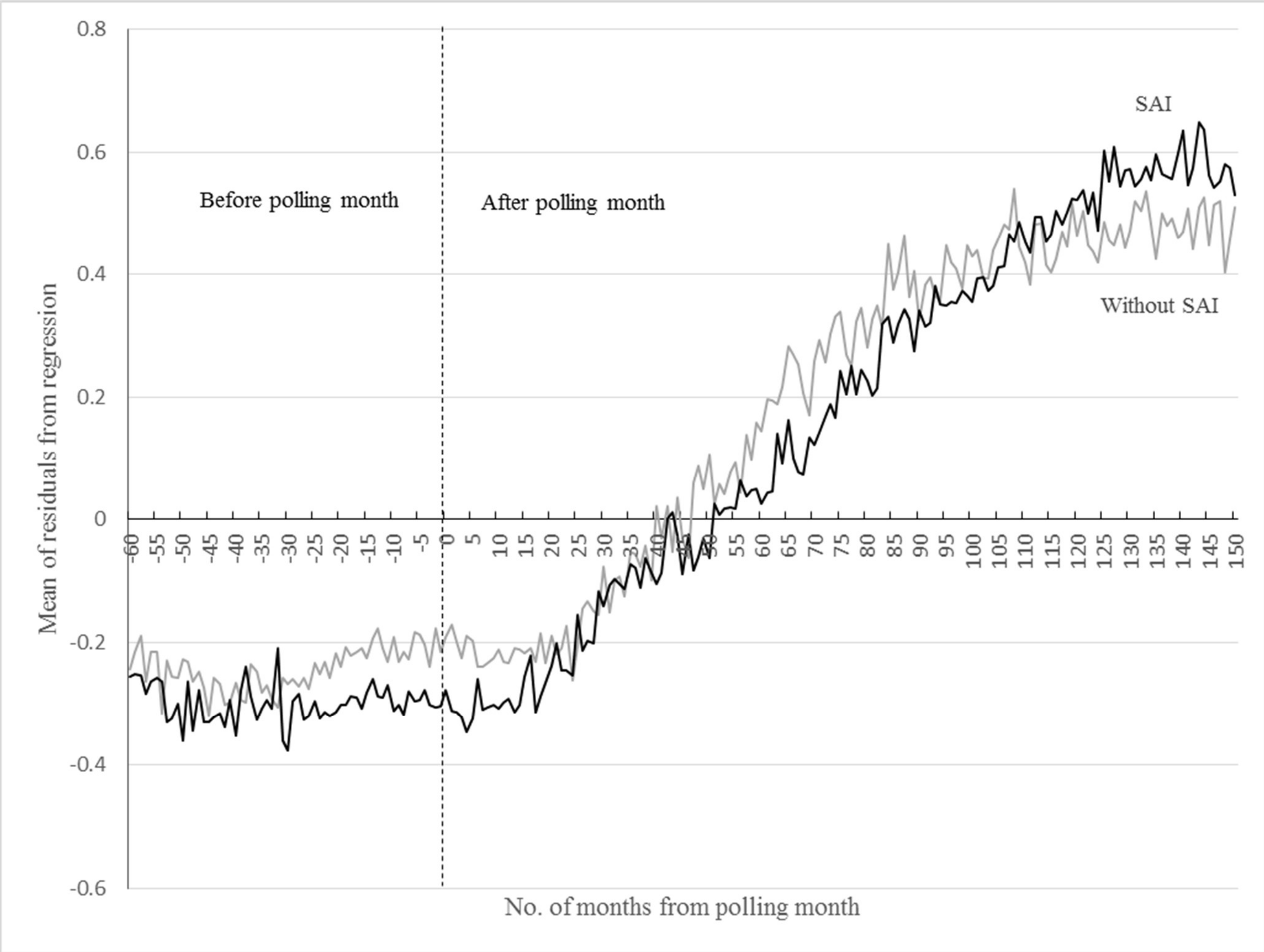


Figure 3b: Monthly mean of residuals from regressing log resale price on block fixed effects

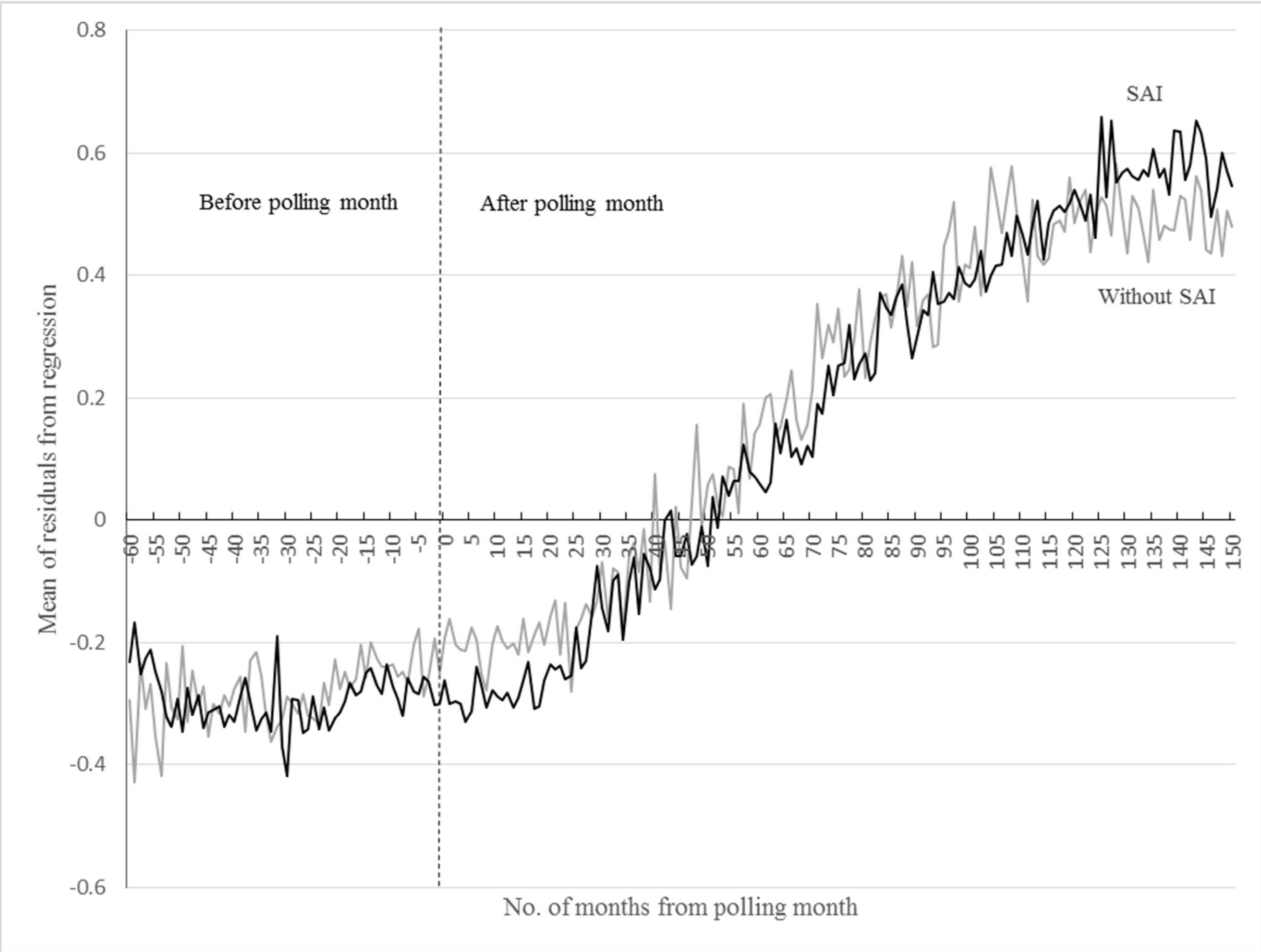
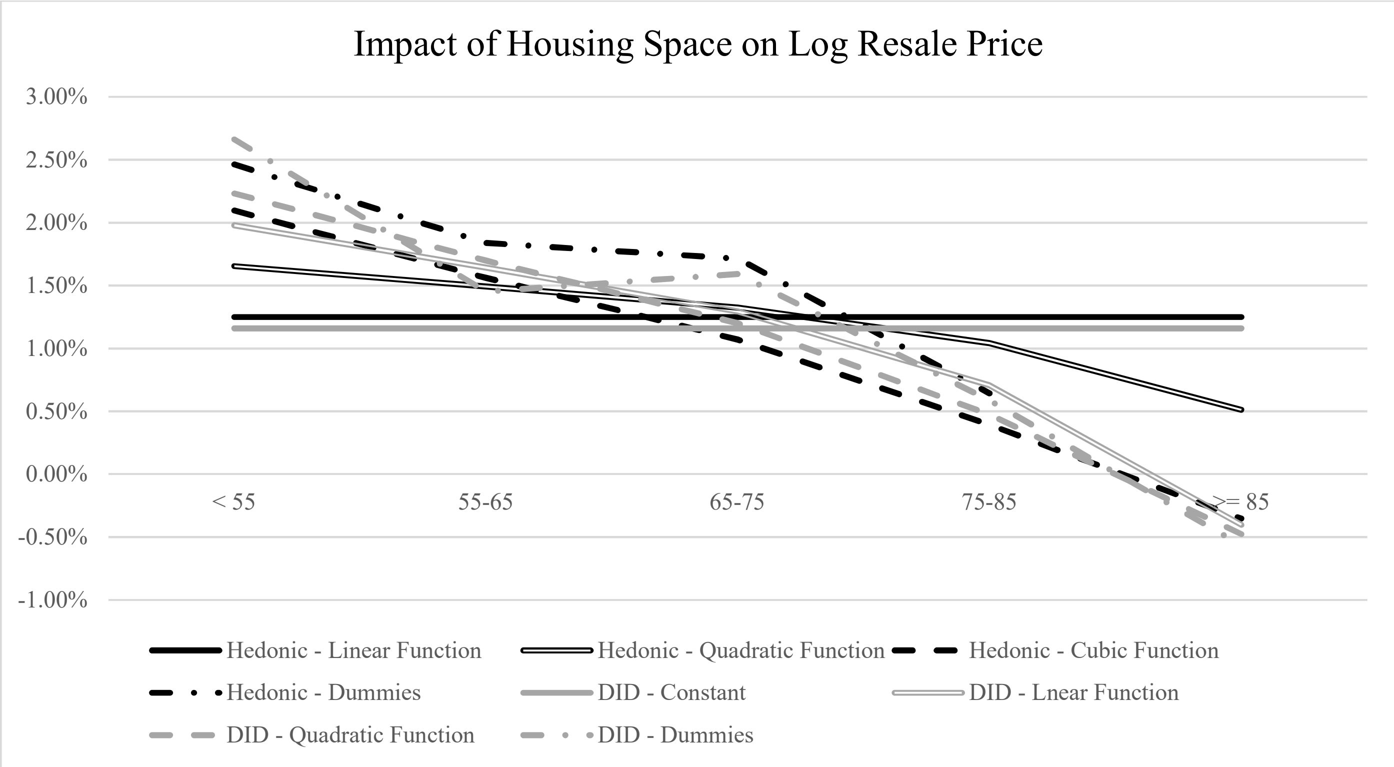


Figure 3c: Monthly mean of residuals from regressing log resale price on block fixed effects (Blocks with polling results 65%-85%[24])

[24] We don't plot the price trend using more restricted sample in the 70% - 80% range because its small sample size prevents us from tracking price changes continuously.


Impact of Housing Space on Log Resale Price
3.00%
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
-0.50%
-1.00%
< 55
55-65
65-75
75-85
>= 85
Hedonic - Linear Function
Hedonic - Quadratic Function
Hedonic - Cubic Function
Hedonic - Dummies
DID - Constant
DID - Lnear Function
DID - Quadratic Function
DID - Dummies

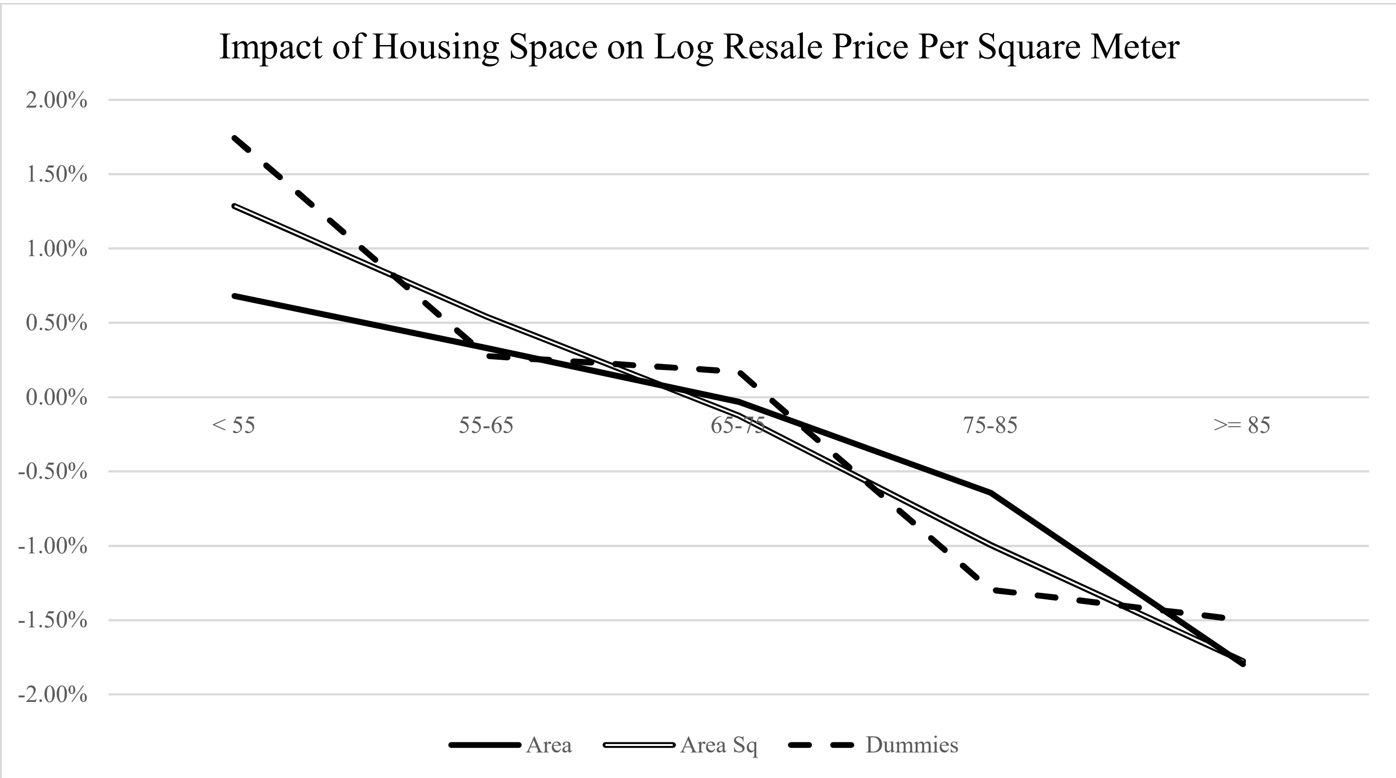

Impact of Housing Space on Log Resale Price Per Square Meter
2.00%
1.50%
1.00%
0.50%
0.00%
-0.50%
-1.00%
-1.50%
-2.00%
< 55
55-65
65-75
75-85
>= 85
Area
Area Sq
Dummies

Figure 4

Appendix

Source: HDB Website, http://services2.hdb.gov.sg/webapp/BB33RESLSTATUS/images/Singapore_Map.jpg

Figure A1: Location of HDB New Towns